



3 1176 00154 6226

DOE/NASA/1044-79/3
NASA TM-79215

NASA-TM-79215 19790020557

EFFECT OF POSITIVE PULSE CHARGE WAVEFORMS ON CYCLE LIFE OF NICKEL-ZINC CELLS

John J. Smithrick
National Aeronautics and Space Administration
Lewis Research Center

July 1979

LIBRARY COPY

AUG 14 1979

LANGLEY RESEARCH CENTER
LIBRARY, NASA
HAMPTON, VIRGINIA

Prepared for
U.S. DEPARTMENT OF ENERGY
Conservation and Solar Applications
Office of Transportation Programs



NF00513

NOTICE

This report was prepared to document work sponsored by the United States Government. Neither the United States nor its agent, the United States Department of Energy, nor any Federal employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DOE/NASA/1044-79/3
NASA TM-79215

EFFECT OF POSITIVE PULSE
CHARGE WAVEFORMS ON CYCLE
LIFE OF NICKEL-ZINC CELLS

John J. Smithrick
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

July 1979

Work performed for
U. S. DEPARTMENT OF ENERGY
Conservation and Solar Applications
Office of Transportation Programs
Washington, D.C. 20545
Under Interagency Agreement EC-77-A-31-1044

N79-28728#

5 amp-hour nickel-zinc cells were selected, rather than traction cells, because the available chargers were limited to modest currents. Three of the charge methods were different positive pulse waveforms (no negative pulses during charge); 120 Hz full wave rectified sinusoidal (FWRS), 120 Hz silicon controlled rectified (SCR), and 1 kHz square wave (SW). The fourth, was a standard constant current method used as a baseline of comparison.

In this paper, the results of positive pulse charge waveforms on the cycle life of 5 amp-hour nickel-zinc cells are presented and discussed.

EXPERIMENTAL

Cell Chargers

The positive pulse chargers and their specifications were (1) 120 Hz full wave rectified sinusoidal (FWRS); voltage range 0 to 10 V, current range 0 to 10 amps and adjustable ratio of peak to average current, (2) 120 Hz silicon controlled rectified (SCR), voltage range 0 to 10 V, current range 0 to 10 amps, adjustable ratio of peak to average current and, adjustable firing angle, (3) 1 kHz square waveform (SW), voltage range of 0 to 25 volts, current range 0 to 10 amps, adjustable ratio of peak to average current, and adjustable duty cycle and, (4) the constant current charger, a commercial unit, voltage range 0 to 50 V, and a current range 0 to 8 amps. Representative charge current waveforms, calculated from oscilloscope voltage traces measured across a shunt during charge, are displayed in figures 1 to 4. Zero charge current occurs when the power supply voltage equals cell voltage.

The FWRS charger was selected on the basis of low cost potential. Relative to a constant voltage charger which requires close voltage regulation (ref. 4), and similarly inexpensive compared to a constant current charger. Simple circuitry should also result in greater reliability, and lighter weight which could be a factor in selecting a charger for on-board electric vehicle use. SCR and constant current chargers were selected as representative of present charge methods. The SW charger was selected because the circuitry was similar to existing electric vehicle chopper controller circuitry, which could be utilized for an on-board charger. The positive pulse chargers were designed and fabricated at the Lewis Research Center from commercially available state-of-the-art components. The constant current charger was a commercially available unit.

Measurements and Procedures

For these experiments, the quantities measured and their accuracies were: average charge current ($\pm 0.3\%$), peak charge current ($\pm 3\%$), peak to average charge current ratio ($\pm 3\%$), discharge current ($\pm 0.3\%$), amp-hours into cell during charge ($\pm 0.5\%$), amp-hours out of cell during discharge ($\pm 0.5\%$), individual cell voltage during charge and discharge ($\pm 0.3\%$).

The average charge current was calculated from the average voltage measured with an integrating digital voltmeter across a shunt. The peak charge current was calculated from peak voltage measured across a shunt with an oscilloscope. From these values, the peak to average current ratio was calculated. The discharge current was also calculated from the voltage measured across a shunt. Conventional amp-hour meters were used to measure the amp-hours into a cell during charge and out of a cell during discharge.

The 5 amp-hour nickel-zinc cells, used in these experiments, were built at the Lewis Research Center and were similar to those used for separator evaluation (ref. 6). They contained the "Astropower" inorganic-organic separator with 35% KOH. A total of 12 cells were randomly selected and divided into four groups of three. The three cells in each group were electrically connected in series, and charge/discharge cycled using each of the previously described methods. The cells were cycled in the sealed state and were not vented at any time during the tests.

A charge/discharge cycle consisted of charging the cells by each method, at the average $c/20$ rate (0.25 A). A 5% overcharge was used for each cycle to compensate for self-discharge of the nickel electrode. Charge currents peak to average charge current ratio, and duty cycle of each representative charge waveform (figs. 1 to 4) used during the life cycle experiments are summarized in table I. The firing angle for the SCR was set at 70° .

During the discharge portion of a cycle, a constant $c/2.5$ (2 A) rate was used. Voltage and amp-hours removed from each cell were monitored and the discharge was terminated when either cell voltage was 1 volt or capacity removed was 3.75 amp-hour (75% depth of discharge). When a cell reached one of the two termination criteria above, it was removed from the series string and discharge was continued on the remaining cells until the next cell met the discharge criteria. Each cell in the series string was cycled to failure. The failure cycle was defined as the cycle in which the output capacity at termination fell below 50% (1.9 A-hr) of the capacity obtained in the first discharge cycle (3.75 A-hr). After

failure, a cell was charged, removed from the test, and its open circuit voltage was monitored as a function of storage time to determine whether or not the cell had an internal short.

RESULTS AND DISCUSSION

Figures 5 to 8 summarize the relative percentage amp-hours output (relative to cycle 1 = 100%) for the 5 amp-hour nickel-zinc cells as a function of cycles completed for the four different charge waveforms. In these figures the location of each cell in the series string is designated by the legend, i.e., 1 and 3 were end cells and 2 was in the center. The best and worst cells' cycles to failure are summarized in table II.

The data spread noted is probably due to variability among the randomly selected test cells. This is unavoidable with nonproduction cells.

A statistical analysis of the cycle data was performed. Confidence intervals were calculated based on a T-test at the 95% confidence level using a pooled standard deviation (ref. 7).

Figure 9 summarizes the average cycle life at failure, and confidence intervals for cells exercised under each of the charge methods. The spread in the data indicates no significant difference in average cycle life using the 120 Hz FWRS, 1 kHz SW, or constant current charge method. There was an apparent difference using the SCR charge method. Unfortunately, this may have been due to an inadvertent severe overcharge of 500% which occurred at cycle number 82. This would be expected to severely shorten the cycle life of a cycle. It should be noted that one cell failed prior to the severe overcharge. Therefore, the analysis of the results on the SCR charge method is ambiguous.

Results of this work suggest that a relatively inexpensive full wave rectifier charger could be used to charge nickel-zinc cells with no significant loss in average cycle life compared to more expensive charge methods. A 1 kHz square wave charger could also be used with no loss in average cell cycle life suggesting the possibility of utilizing existing electric vehicle chopper controller circuitry for on-board charger. Pulse charging of the types investigated did not lead to any increase in cycle life over that for constant current charging.

The failure mechanism was determined from open circuit voltage stand. The voltage of a charged cell was monitored as a function of stand time. Results of a representative cell is shown in figure 10. The steady drop in open circuit voltage indicates that self-discharge due to internal shorting contributed to cell degradation.

CONCLUDING REMARKS

A relatively inexpensive full wave rectified sinusoidal charger appears feasible for charging 5 amp-hour nickel-zinc cells. This charging method showed no significant loss in average cycle life when compared to the constant current charger. A 1 kHz square wave charger could also be used with no significant loss in average cycle life; and suggests the possibility of utilizing existing electric vehicle chopper controller circuitry for an on-board charger. Pulse charging of the types investigated did not improve cell cycle life over that for constant current in the 5 amp-hour nickel-zinc cells.

REFERENCES

1. Weininger, J. L.; and Siwek, E. G.: A System Evaluation of Lead-Acid Battery Chargers: Part 1. Cells With Antimonial Positive Grids. J. Power Sources, vol. 2, no. 4, 1978, pp. 301-316.
2. Fader, B.; and Van Handle, H.: Life Cycle Test of a 6-Volt Calcium-Lead Standby Battery Using a Mas Gas-Controlled Charger. Report No. 4454, American Smelting and Refining Company, 1971.
3. Behrin, E. P.; et. al.: Energy Storage Systems for Automotive Propulsion, Vol. 2 - Detailed Report. UCRL-52303 Vol.-2, Lawrence Livermore Labs., Univ. of California, 1977.
4. Mueller, G. A.: The Gould Battery Handbook. Gould, Inc., Mendota Heights, Minn., 1973.
5. Mas, Joseph A.: The Charging Process. Second International Electric Vehicles Symposium, Electric Vehicle Council, 1971, pp. 228-246.
6. Sheibley, D. W.: New Separators for Nickel-Zinc Batteries. NASA TM X-3465, 1976.
7. Dixon, W. J.; and Massey, F. J., Jr.: Introduction for Statistical Analysis. Third ed., McGraw Hill Book Co., Inc. 1969.

TABLE I. - CHARGE CURRENT AND DUTY CYCLE OF
EACH REPRESENTATIVE CHARGE WAVEFORM

Charger waveform	Peak current, A	Average current, A	<u>Peak current</u> average current	Duty cycle, %
120 Hz FWRS	0.5	0.25	2.0	68
120 Hz SCR	.6	.24	2.5	57
1 kHz SW	.7	.25	2.8	36
CC	.25	.25	1.0	100

TABLE II. - CYCLES TO FAILURE FOR
BEST AND WORST CELLS USING THE
FOUR DIFFERENT CHARGE WAVEFORMS

Charger waveform	Cycles to failure	
	Best cell	Worst cell
Constant current	352	203
120 Hz FWRS	328	219
1 kHz SW	343	133
120 Hz SCR	100	67

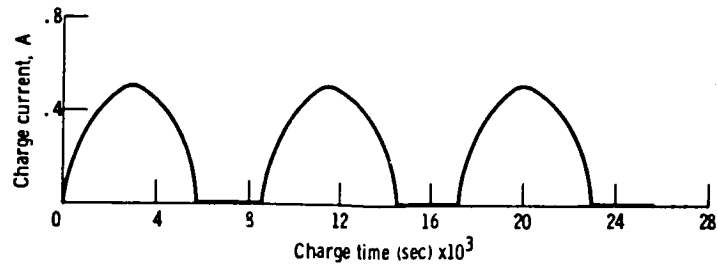


Figure 1. - Charge current as a function of charge time for 120 Hz full wave rectified sinusoidal charger.

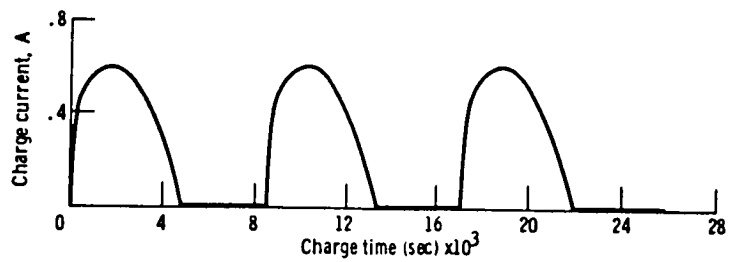


Figure 2. - Charge current as a function of charge time for a 120 Hz silicon controlled rectified charger.

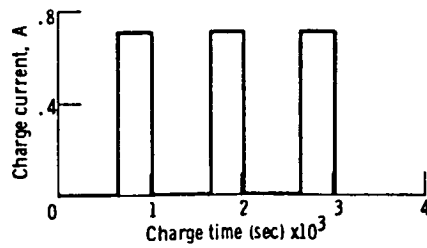


Figure 3. - Charge current as a function of charge time for 1 kHz square wave charger.

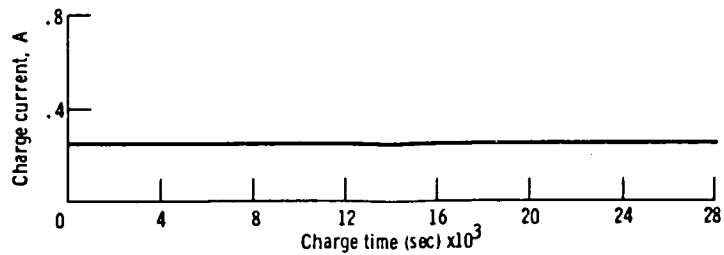


Figure 4. - Charge current as a function of charge time for constant current charger.

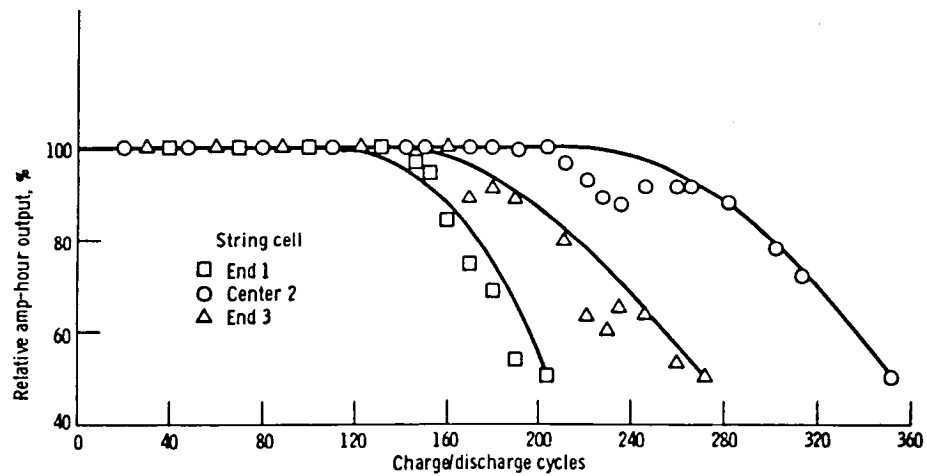


Figure 5. - Relative percentage amp-hours output of 5 amp-hour nickel-zinc cells as a function of cycles for constant-current charge method.

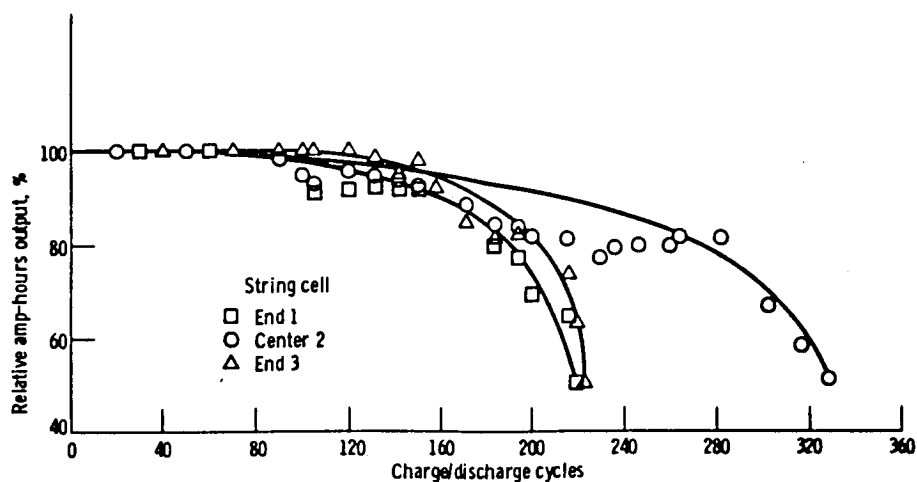


Figure 6. - Relative percentage amp-hours output of 5 amp-hour nickel-zinc cells as a function of cycles for 120 Hz full wave rectified sinusoidal charger.

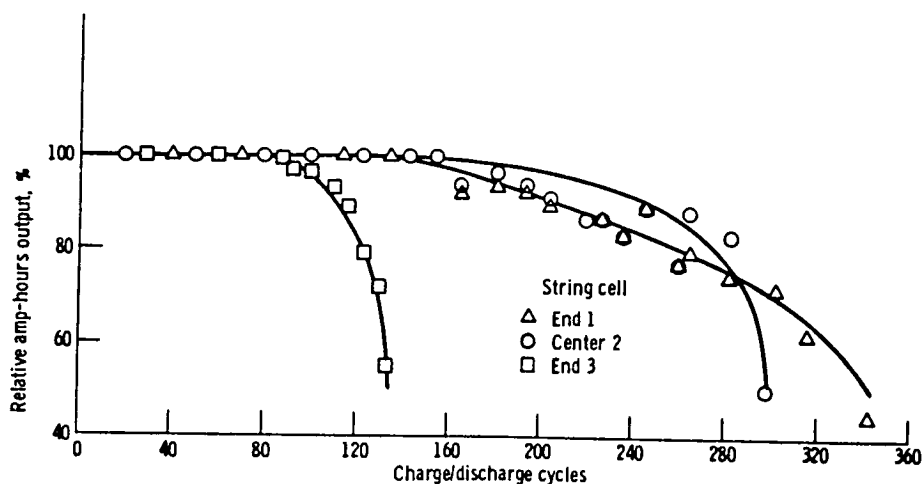


Figure 7. - Relative percentage amp-hours output of 5 amp-hour nickel-zinc cells as a function of cycles for 1 kHz square wave charger.

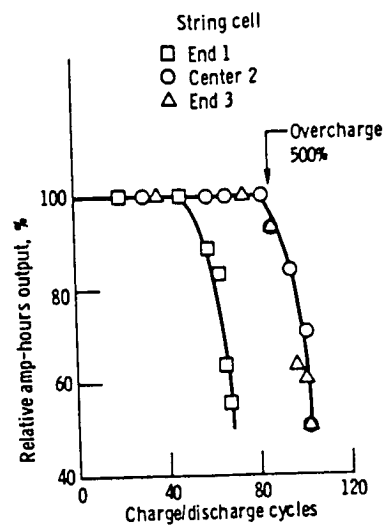


Figure 8. - Relative percentage amp-hours output of 5 amp-hour nickel-zinc cells as a function of cycles for silicon controlled rectified charger.

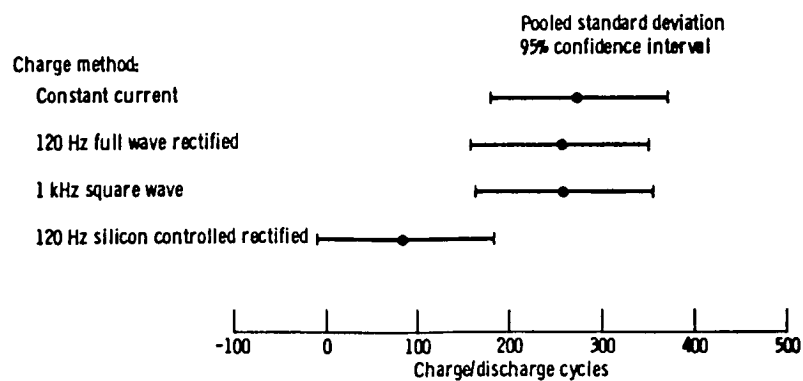


Figure 9. - Average cycle life at failure and confidence intervals for charge methods.

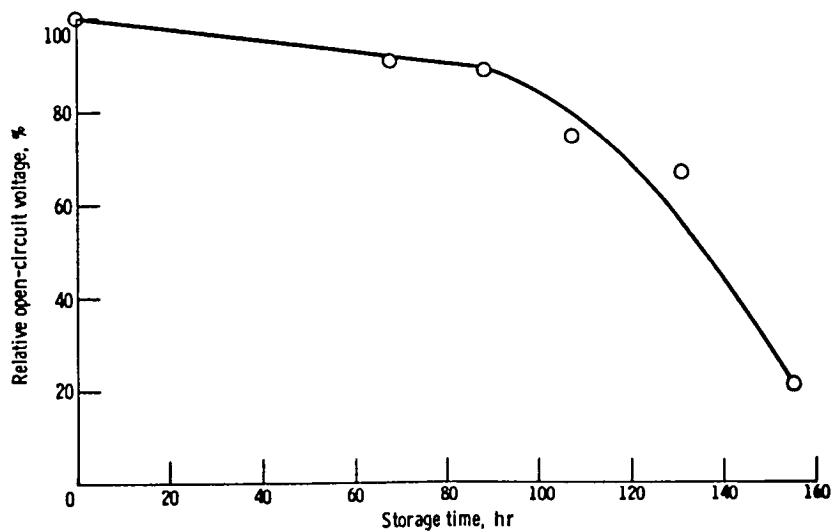


Figure 10. - Relative open-circuit voltage as a function of storage time for a representative failed cell.

1. Report No. NASA TM-79215		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle EFFECT OF POSITIVE PULSE CHARGE WAVEFORMS ON CYCLE LIFE OF NICKEL-ZINC CELLS				5. Report Date July 1979	
				6. Performing Organization Code	
7. Author(s) John J. Smithrick				8. Performing Organization Report No. E-100	
				10. Work Unit No.	
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135				11. Contract or Grant No.	
				13. Type of Report and Period Covered Technical Memorandum	
12. Sponsoring Agency Name and Address U. S. Department of Energy Office of Transportation Programs Washington, D. C. 20545				14. Sponsoring Agency Code Report No. DOE/NASA/1044-79/3	
15. Supplementary Notes Final report. Prepared under Interagency Agreement EC-77-A-31-1044.					
16. Abstract Five amp-hour nickel-zinc cells were life cycled to evaluate four different charge methods. Three of the four waveforms investigated were 120 Hz full wave rectified sinusoidal (FWRS), 120 Hz silicon controlled rectified (SCR), and 1 kHz square wave (SW). The fourth, a constant current method, was used as a baseline of comparison. Three sealed Ni-Zn cells connected in series were cycled. Each series string was charged at an average c/20 rate, and discharged at a c/2.5 rate to a 75% rated depth. Results indicate that the relatively inexpensive 120 Hz FWRS charger appears feasible for charging 5 amp-hour nickel-zinc cells with no significant loss in average cycle life when compared to constant current charging. The 1-kHz SW charger could also be used with no significant loss in average cycle life, and suggests the possibility of utilizing the existing electric vehicle chopper controller circuitry for an on-board charger. There was an apparent difference using the 120 Hz SCR charger compared to the others, however, this difference could be due to an inadvertent severe overcharge, which occurred prior to cell failure. The remaining two positive pulse charging waveforms, FWRS and 1 kHz, did not improve the cycle life of 5 amp-hour nickel-zinc cells over that of constant current charging.					
17. Key Words (Suggested by Author(s))			18. Distribution Statement Unclassified - unlimited STAR Category 44 DOE Category UC-94c		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages	
				22. Price*	

End of Document